# Irrigation Energy Source Alternatives

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## Introduction

This paper provides documentation for Pump.xls, an Excel spreadsheet, designed to compare two energy sources for pumping irrigation water. Changing energy sources requires changing or modifying the power unit and often some of other components of the irrigation system. For example, changing a pivot from electricity to natural gas may require the addition of a generator to generate electricity for the tower motors. This spreadsheet estimates the annual operating costs for a producer's existing system and then compares those costs to projected operating costs for a proposed alternative. The operating costs include fuel, connect charges, parts, labor, engine oil, and drive oil. The user provides information regarding current pumping plant specifications. The user can also provide their own estimates of the annual operating costs if they know those costs. The spreadsheet then uses the difference in the annual operating costs to estimate the present value of that difference over a period of years and at a rate of return provided by the user. That present value (if positive) is the amount that would be available to pay for a conversion, which would be fully paid for in the specified years by the savings in annual operating costs. If the differences are negative it means that the present system has lower annual operating costs than the proposed change.

In addition to estimating the savings in operating costs with conversion, the spreadsheet provides an estimate of the total annual costs of the systems under comparison. Total annual costs include the operating costs discussed above plus ownership costs. Ownership costs include depreciation, insurance, interest on the investment, and personal property tax. Just because an alternative system has lower operating costs and the difference in operating costs would pay for conversion to that alternative system does not necessarily mean that its total costs are lower. Also, it may be profitable to switch systems due to lower total annual costs even though the new system's operating costs are expected to be higher than the existing system.

## How the spreadsheet estimates costs

Operating costs. Fuel costs, the major component of operating costs, include connect charges for natural gas and electricity and the cost of the fuel used. The amount of fuel used depends on the work required to deliver the water, referred to as the water horsepower (WHP), and the fuel required per WHP. The spreadsheet uses 100% of the Nebraska performance criteria as a default value for the fuel consumption. Users can change the fuel consumption to reflect actual experience by modifying the actual field performance %. The natural gas connect fee is expressed as an annual flat rate and the electric connect fee is based on the brake horsepower (BHP) of the motor (equation 4 in the appendix). The user must specify unit costs for the fuel and connect charges. The specific formulas used to estimate fuel use are shown as equations 1-3 in the Appendix.

For fossil-fueled engines, 15% of the calculated BHP is added to the calculated BHP to approximate the BHP rating system used by manufacturers. The cost of parts is estimated using BHP and depends on the energy source. Repair labor is estimated as a function of the pumping hours and the wage paid the mechanic. The cost of engine and drive oil is estimated using the WHP-hours, i.e. the hours of operation at the WHP required as shown in Appendix equation 5.

Ownership Costs. Annual depreciation is a function of the cost of the components, the salvage value, and the years of useful life. The spreadsheet uses a simple linear formula for estimating depreciation (see equation 6 in Appendix). Insurance, interest, and personal property tax are estimated as a percentage of the average annual investment. Average annual investment is determined as an average of the value at the beginning of the first year (purchase cost) and the value at the beginning of the last year (salvage value plus the annual depreciation) as shown in Appendix equation 7.

## How to use the spreadsheet

There are five worksheets in this spreadsheet: Inputs, Existing System, Modified System, Comparisons, and Look-up Tables. The user can change any cell that contains blue text. The sheets should be set-up to print six pages, eight if the look-up tables are printed.

## Inputs worksheet

On the *Inputs* sheet, the user specifies the distribution system, pumping rate, area irrigated, acre-inches per acre for the growing season, lift, pressure, and the number of towers if the system is a pivot.

**Inputs**

| | | |
|---|---|---|
| Distribution System | 1 | 1=Center Pivot, 2=other |
| Pumping Rate | 700 | Gallons per Minute (GPM) |
| Area irrigated | 130 | Acres |
| Water applied per acre | 14.3 | Acre-inches/acre (Ac-In/ac) |
| Annual Pumping* | 1,202 | Hours |
| Lift | 170 | Ft |
| Pressure | 60 | Pounds per Square Inch (PSI) |
| If pivot, number of Towers | 7 | (0 if not center pivot) |

*Revise Ac-In/ac or GPM To adjust an nual pumping hours.

The annual hours pumped are calculated using the area irrigated, water applied per acre, and the output of the well expressed in gallons per minute (GPM), so by changing any of these, the hours pumped can be changed. For example, if the operator knows annual hours pumped, area irrigated and GPM but is unsure of water applied per acre, water applied can be changed until the annual hours pumped is correct. These numbers are carried through to the other sheets for quick reference but can only be changed here.

Next, the user can specify the per unit power costs associated with each fuel source, including the wage rate for repairs, and the connect charges.

**Power costs**

| | | $/unit | Repair Wage/hr | Annual Connect Charge |
|---|---|---|---|---|
| Diesel | $/gal | $1.00 | $15.00 | |
| Nat. Gas | $/MCF | $4.00 | $15.00 | $100/well |
| Propane | $/gal | $0.85 | $15.00 | |
| Electric | $/kwh | $0.06 | $15.00 | $8.50/BHP |
| Gasoline | $/gal | $0.95 | $15.00 | |
| Engine Oil | $/Gal | $4.00 | | |
| Drive and Elect. Motor Oil | $/Gal | $3.60 | | |

The input is used to calculate the annual energy cost and repair cost. Table 1 compares the operating cost for each fuel source. Parameters for the system under evaluation are shown at the top of the table

**Table 1: Annual Energy and Repair Cost Comparison for Different Energy Sources**

| Pumping Rate GPM | Acres | Water Pumped Ac-In/acre | Hours Pumped | Lift (ft) | Pressure PSI | Head (ft) | Towers | WHP |
|---|---|---|---|---|---|---|---|---|
| 700 | 130 | 14.3 | 1,202 | 170 | 60 | 309 | 7 | 57 |

| Energy Source | Unit Price | Energy Use/hr* | Annual Energy Cost | Drive and Pump Efficiency % | BHP | Annual Repair Cost** | Annual Connect Charge | Total Annual Operating Cost |
|---|---|---|---|---|---|---|---|---|
| Diesel | $1.00/gal | 4.6 gal | $5,481 | 70 | 102 | $1,187 | | $6,668 |
| Nat. Gas | $4.00/MCF | 0.9 MCF | $4,442 | 70 | 102 | $1,420 | $100 | $5,961 |
| Propane | $0.85/gal | 8.3 gal | $8,452 | 70 | 102 | $1,420 | | $9,872 |
| Electric | $0.06/kwh | 64.4 kwh | $4,645 | 75 | 83 | $484 | $706 | $5,835 |
| Gasoline | $0.95/gal | 6.6 gal | $7,516 | 70 | 102 | $1,512 | | $9,028 |

*Energy use at 100% Nebraska Performance Criteria

**Repair Costs include repair labor, engine/motor oil, and drive oil

## Existing and Modified System Worksheets

The next two sheets are identical. The first sheet, "existing system," is used for the current fuel source and the second sheet, "modified system," is used for an alternative fuel source. The fuel source code number from a list to the right of the cell must be entered at the top of both the "existing" and "modified" system worksheets. Entering the fuel source will change the references to and calculations for the selected fuel comparisons throughout the remainder of the worksheet.

| | | | |
|---|---|---|---|
| Fuel Source | 2 | 1=Diesel | 3=Propane Gas |
| | | 2= Natural Gas | 4=Electricity |
| | | | 5=Gasoline |

The rest of the inputs are carried over from the *Inputs* sheet. The column, " Nebraska Performance Criteria %", can be modified by the user to change the overall energy consumption (Appendix Equation (3)). This indicated how well the pumping plant is performing in relation to the Nebraska Criteria. The BHP is calculated here by using the WHP, drive and pump efficiency %, number of towers for a pivot system, and a 15% increase for a fossil fueled system, as shown in Appendix Equation (4).

**Calculated Constants**

| Hours Pumped | Head | WHP | Nebraska Perform. Criteria % | Fuel Usage | Drive and Pump Efficiency % | BHP Required |
|---|---|---|---|---|---|---|
| 1,202 | 309 | 57 | 75 | 1.23MCF/hr | 70 | 102 |

Table 2 *Operating Costs*, under the "existing system," (Table 5 for "modified system") sheet begins with the above listing of calculated constants. The BHP listed is the closest matching BHP from the look-up tables to match the calculated BHP requirement. The column marked *Calculated* estimates cost based on the inputs given. The *User* column allows the operator to enter a value different from the calculated value. For example if the user knows the actual fuel cost for the existing system he can enter that amount and that amount will be used to calculate costs in this table and throughout the worksheet

| **Table 2: Operating Costs-Existing System** | 125BHP | Calculated | User | |
|---|---|---|---|---|
| Fuel | Fuel/hr*hrs pumped*unit cost | $5,922.33 | $0 | $5,922 |
| Hook-up Cost | | $100.00 | $0 | $100 |
| Parts | $2.40/BHP/1000 hrs | $360.60 | $400 | $400 |
| Repair Labor | 40 hrs Labor/1,000 hrs*Repair Wage | $721.20 | $0 | $721 |
| Engine Oil | 800 whp-hrs/gal | $342.57 | $0 | $343 |
| Drive Oil | 4,000 whp-hrs/gal | $61.66 | $0 | $62 |
| Total Repairs including oil | | $1,486.03 | $0 | $1,486 |
| Total for Existing System | | | | $7,508 |

If a value is not known, leave the *User* column at "0". If all of the user values are zero, then the total for existing system will equal the total on the *Inputs* page under *Total Annual Operating Cost.*

Scrolling to the right from Table 2 (or Table 5 for "modified system") accesses Table 3 for the "existing system" (Table 6 for "modified system"). Table 3 (or 6 for "modified system") displays the cost of the listed components. As the fuel source changes, the list of components changes to match those required for that fuel source. The last two lines in Table 3 (Table 6) are available to the user to add components. The *Quantity* column allows changes in the amount of each component. The only quantity that cannot be changed here is the number of bowls. To change the number of bowls, change the number in the table to the right of Table 3 (Table 6) that looks as shown here.

| | Calculated | User |
|---|---|---|
| # Bowls | 7 | 0 |

**Table 3: Component Costs-Existing System**

| Component | Quantity | Unit Price* | Total Cost | Years Life | Salvage | Avg Annual Depreciation |
|---|---|---|---|---|---|---|
| Well Site | | | | | | |
| Pump Base, Generator Mount | 1 | $1,958.00 | $1,958 | 25 | $0 | $78 |
| | 0 | $0.00 | $0 | 20 | $0 | $0 |
| | 0 | $0.00 | $0 | 20 | $0 | $0 |
| | 0 | $0.00 | $0 | 50 | $0 | $0 |
| Pump | | | | | | |
| 1st bowl | 1 | $0.00 | $1,347 | 18 | $0 | $75 |
| additional bowls | 6 | $0.00 | $2,982 | 18 | $0 | $166 |
| Gear Head, Drive Shaft | 1 | $0.00 | $2,411 | 15 | $0 | $161 |
| Nat. Gas Engine 125 BHP | 1 | $0.00 | $5,948 | 6 | $0 | $991 |
| Pivot | | | | | | |
| Generator | 1 | $0.00 | $2,100 | 15 | $0 | $140 |
| | 0 | | | | | |
| | 0 | $0.00 | $0 | 0 | $0 | $0 |
| | 0 | $0.00 | $0 | 0 | $0 | $0 |
| Total | | | $16,746 | | $0 | $1,611 |

The user inputs the price paid for each unit of a component under *Unit Price* in Table 3 for the "existing system" (Table 6 for "modified system"). If the cost is unknown, leave the unit price zero and the program will look-up the value in the look-up tables to calculate the total cost. Values for the *Years Life* and *Salvage* value also must be entered. Total cost and depreciation are shown at the bottom of Table 3 (Table 6).

The average annual investment is calculated under *Ownership Costs* in Table 4 for the "existing system" (Table 7 for "modified system"), which is reached by scrolling down from Table 3 (Table 6). The worksheet automatically enters depreciation from Table 3 (Table 6). The user needs to input percentage rates for insurance and personal property tax. In some states personal property tax is calculated on the irrigation pumping plant. The user may or may not have insurance on the equipment. If personal property tax or insurance do not apply the rates should be set to 0. The costs for these items are calculated as the entered percent times the average annual investment value. The real interest rate is the difference between the interest rate and the inflation rate. These can be entered in the table to the right of Table 4 (Table 7). The interest rate should be based on the rate one could expect to pay for borrowed money to install the modified system or the opportunity cost (alternative return) on money used internally if a loan is unnecessary. The inflation rate is the rate for general goods and services and has ranged from about 2.5 to 3.5% in recent years.

| | % |
|---|---|
| Interest Rate | 9.0 |
| Inflation Rate | 2.5 |
| Real Interest Rate | 6.5 |

The annual average investment is multiplied by the insurance, real interest, and personal property tax rates in Table 4 (Table 7). The total ownership cost is calculated by summing the depreciation, insurance, interest, and personal property tax. The total annual cost is then calculated by adding the operating cost and the ownership cost.

**Table 4: Total Annual Costs-Existing System**

Ownership Costs

| | | |
|---|---|---|
| Avg Annual Investment | | $9,178 |
| | % | |
| Depreciation | | $1,611 |
| Insurance | 0.00 | $0 |
| Interest on investment | 6.5 | $597 |
| Personal Property Tax | 0.00 | $0 |
| | Total | $2,207 |
| **Operating Costs** | | $7,508 |
| **Total Annual Cost** | | $9,716 |

Tables 5-7 are not shown here for the *Modified System* sheet since they are identical in form and use as Tables 2-4 in the *Existing System*.

## Comparisons Worksheet

The *Comparison* sheet compares the costs of the existing and modified systems based on the information given by the user. The sheet begins with Table 8 and ends with Table 12. Scrolling down from Table 8 will reveal successive tables. Table 8, *Expected Fuel Use Comparisons*, compares how much fuel is used per hour, per acre, per acre-inch, and per year.

**Table 8: Expected Fuel Use Comparisons**

| | Existing System Nat. Gas | | Modified System Electric | |
|---|---|---|---|---|
| Nebraska Performance Criteria | 75 | % | 75 | % |
| | 1.2 | MCF/hr | 85.9 | kwh/hr |
| | 11.4 | MCF/acre | 794.0 | kwh/acre |
| | 0.8 | MCF/Ac-In | 55.5 | in/Ac-In |
| | 1,481 | MCF/year | 103,223 | kwh/year |
| Drive and Pump Efficiency | 70 | % | 80 | % |
| BHP requirement | 102 | BHP | 79 | BHP |
| Engine/Motor Size | 125 | BHP | 100 | BHP |

Table 9, *Annual Operating Cost Differences*, shows the difference in operating costs of the two systems at a range of fuel prices. A negative number in this table indicates the current system is cheaper to operate.

**Table 9: Annual Operating Cost Differences-including repairs and hookup costs (Nat. Gas - Electric)**

| | | Nat. Gas cost per MCF | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $2.8000 | $3.2000 | $3.6000 | $4.0000 | $4.4000 | $4.8000 | $5.2000 | $5.6000 |
| Electric cost per kWH | $0.0420 | $50 | $642 | $1,234 | $1,826 | $2,418 | $3,011 | $3,603 | $4,195 |
| | $0.0480 | ($570) | $22 | $615 | $1,207 | $1,799 | $2,391 | $2,984 | $3,576 |
| | $0.0540 | ($1,189) | ($597) | ($5) | $588 | $1,180 | $1,772 | $2,364 | $2,956 |
| | $0.0600 | ($1,808) | ($1,216) | ($624) | ($32) | $560 | $1,153 | $1,745 | $2,337 |
| | $0.0660 | ($2,428) | ($1,836) | ($1,243) | ($651) | ($59) | $533 | $1,126 | $1,718 |
| | $0.0720 | ($3,047) | ($2,455) | ($1,863) | ($1,270) | ($678) | ($86) | $506 | $1,098 |
| | $0.0780 | ($3,666) | ($3,074) | ($2,482) | ($1,890) | ($1,298) | ($705) | ($113) | $479 |

Table 10 reports the break-even investment for the conversion at different fuel prices. Break-even investment is the dollar amount that can be recovered from annual cost savings at the specified interest rate. The user needs to input the interest rate and the desired recovery period at the top of Table 10. An appropriate interest rate may be the rate for borrowing money to make the conversion or the rate of return on the operator's money. The recovery period depends on how soon the operator believes the cost savings should pay for the conversion. A negative number here means the new system will not provide any savings in operating costs; instead it will take more money to operate for that combination of fuel prices.

**Table 10: Break Even Investment for Conversion from Nat. Gas to Electric**

Interest Rate 5.00%
Recovery Period 5 years

| | | Nat. Gas cost per MCF | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $2.8000 | $3.2000 | $3.6000 | $4.0000 | $4.4000 | $4.8000 | $5.2000 | $5.6000 |
| Electric cost per kWH | $0.0420 | $214 | $2,779 | $5,343 | $7,907 | $10,471 | $13,035 | $15,599 | $18,163 |
| | $0.0480 | ($2,467) | $97 | $2,661 | $5,225 | $7,789 | $10,353 | $12,917 | $15,481 |
| | $0.0540 | ($5,148) | ($2,584) | ($20) | $2,544 | $5,108 | $7,672 | $10,236 | $12,800 |
| | $0.0600 | ($7,830) | ($5,266) | ($2,702) | ($138) | $2,426 | $4,991 | $7,555 | $10,119 |
| | $0.0660 | ($10,511) | ($7,947) | ($5,383) | ($2,819) | ($255) | $2,309 | $4,873 | $7,437 |
| | $0.0720 | ($13,193) | ($10,628) | ($8,064) | ($5,500) | ($2,936) | ($372) | $2,192 | $4,756 |
| | $0.0780 | ($15,874) | ($13,310) | ($10,746) | ($8,182) | ($5,618) | ($3,054) | ($490) | $2,074 |

Table 11 shows how the total annual cost of the new system compares to the old system for a range of fuel prices. Even though the conversion cost may not be recovered in the recovery period specified in Table 10, the modified system may be cheaper to own and operate in the long run using the years life specified in Table 3 (*Existing System*) and Table 6 (*Modified System*)

**Table 11: Annual Ownership and Operating Cost by Energy Price Levels**

| Existing System Nat. Gas | | Modified System Electric | |
|---|---|---|---|
| Price | Annual Cost | Price | Annual Cost |
| $2.4000 | $7,347 | $0.0360 | $6,119 |
| $2.8000 | $7,939 | $0.0420 | $6,739 |
| $3.2000 | $8,531 | $0.0480 | $7,358 |
| $3.6000 | $9,124 | $0.0540 | $7,977 |
| $4.0000 | $9,716 | $0.0600 | $8,597 |
| $4.4000 | $10,308 | $0.0660 | $9,216 |
| $4.8000 | $10,900 | $0.0720 | $9,835 |
| $5.2000 | $11,493 | $0.0780 | $10,455 |
| $5.6000 | $12,085 | $0.0840 | $11,074 |

Table 12 allows the user to determine if it would be worthwhile to wait another year before converting to another system. The user needs to input the estimated current value of the system and the value the system would have at the end of the year.

**Table 12: Cost Next Year of Existing System vs Avg Annual Cost of Modified System**

| Existing System Components | Value | Year End | Depreciation |
|---|---|---|---|
| Well Site | | | |
| Pump Base, Engine Stand | $1,348 | $1,281 | $67 |
| | | | $0 |
| | $0 | $0 | $0 |
| | $0 | $0 | $0 |
| Pump | | | |
| 1st bowl | $972 | $897 | $75 |
| additional bowls | $5,837 | $5,388 | $449 |
| Gear Head, Drive Shaft | $1,465 | $1,319 | $146 |
| Nat.Gas Engine 125 BHP | $5,350 | $4,585 | $765 |
| Pivot | | | |
| Generator | $1,400 | $1,260 | $140 |
| | | | $0 |
| | $0 | $0 | $0 |
| | $0 | $0 | $0 |
| Total | $16,372 | $14,730 | $1,642 |

| | | |
|---|---|---|
| Avg Annual Investment | | $16,372 |
| | % | |
| Depreciation | | $1,642 |
| Insurance | 0.00 | $0 |
| Interest | 6.50 | $1,064 |
| Personal Property Tax | 0.00 | $0 |
| Total | | $2,706 |

The program then calculates the difference in annual cost between the old and new system. A negative number means that the current system would be cheaper for another year.

| Electric cost per kWH | Nat. Gas cost per MCF | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $2.8000 | $3.2000 | $3.6000 | $4.0000 | $4.4000 | $4.8000 | $5.2000 | $5.6000 |
| $0.0420 | $1,699 | $2,291 | $2,884 | $3,476 | $4,068 | $4,660 | $5,253 | $5,845 |
| $0.0480 | $1,080 | $1,672 | $2,264 | $2,856 | $3,449 | $4,041 | $4,633 | $5,225 |
| $0.0540 | $460 | $1,053 | $1,645 | $2,237 | $2,829 | $3,422 | $4,014 | $4,606 |
| $0.0600 | ($159) | $433 | $1,026 | $1,618 | $2,210 | $2,802 | $3,395 | $3,987 |
| $0.0660 | ($778) | ($186) | $406 | $998 | $1,591 | $2,183 | $2,775 | $3,367 |
| $0.0720 | ($1,398) | ($805) | ($213) | $379 | $971 | $1,564 | $2,156 | $2,748 |
| $0.0780 | ($2,017) | ($1,425) | ($832) | ($240) | $352 | $944 | $1,537 | $2,129 |

## Look-up Tables Worksheet

The *Look-up Tables* present some estimates of current values for each component. These are the default values for the given component using the given requirements unless overridden by input from the producer.

## Appendix

Equations used in the spreadsheet to estimate various components of cost are presented here.

Water Horse Power (WHP)

$$WHP = \frac{Head * GPM}{3960} + (0.3 * \text{Number of Towers}) \quad (1)$$

**where**

$$Head = Lift + (2.31 * PSI) \quad (2)$$

**Lift = distance from pump discharge to draw-down inside well**
**PSI=pressure of system in pounds per square inch**
**GPM=gallons per minute pumped**

### Fuel or energy usage

$$\text{Usage(gal/hr or Kwh/hr)} = \frac{\frac{WHP}{\text{whp - hrs/gal or Kwh}}}{\text{Nebraska Performance Criteria \%}} \quad (3)$$

### Brake Horse Power (BHP)

$$BHP = [\frac{\frac{Head * GPM}{3960}}{\text{Drive and Pump Efficiency \%}} + (1.5 * \text{Towers})] x 1.15 \text{ if fossil fueled} \quad (4)$$

**Hours Pumped**

$$\text{Hours} = \frac{\text{Acre Inches Applied per Acre} * \text{Acres} * 27{,}154 \text{ gal/AcIn}}{\text{GPM} * 60 \text{ min/hr}} \quad (5)$$

**Average Annual Depreciation (AAD)**

$$\text{AAD} = \frac{\text{Total Price - Salvage}}{\text{Years Life}} \quad (6)$$

**Average Annual Investment (AAI)**

$$\text{AAI} = \frac{\text{Total Price} + \text{Salvage} + \text{Average Annual Depreciation}}{2} \quad (7)$$